CT Pulmonary Angiography During Pregnancy

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July 2016
Why Radiology?
What are we trying to achieve?

- Diagnostic scan
- Radiation dose as low as reasonably achievable
- Contrast dose to a minimum
- No repeat scans
- Keep patient calm
Outline

1. Pathology & Imaging Pathway

2. Scan Technique & Radiation Dose

3. Physiology & Contrast Injection

Sorry Mum!
Outline

1. Pathology & Imaging Pathway

2. Scan Technique & Radiation Dose

3. Physiology & Contrast Injection
1. Pathology & Imaging Pathway

➢ Rudolf Virchow (1821-1902)

➢ German Anatomist & Physicist

➢ Coined the terms embolism and thrombosis

➢ Described factors contributing to venous thrombosis

➢ These are known as Virchow’s Triad
Pregnancy can be the perfect storm of Virchow’s Triad causing thromboembolism:

- Stasis
- Hypercoaguoble blood
- Vascular damage
Pulmonary embolism in pregnancy

Ghada Bourjeily, Michael Paidas, Hanan Khalil, Karen Rosene-Montella, Marc Rodger

*Lancet* 2010; 375: 500-12

Pulmonary embolism (PE) is the leading cause of maternal mortality in the developed world.

- Prevention, diagnosis and therapeutic management of PE in pregnant women are all complicated by a shortage of validated approaches in this unique population.

- Incidence of antenatal PE estimated to be 5-12 events per 10,000. Incidence of postpartum PE estimated to be 3-7 events per 10,000. This is 15-35 times higher than age matched controls.

- The risk of events is similar across all three trimesters.
Risk factors listed include:

- Thrombophilia (52%)
- Previous venous thrombosis (25%)
- Family history (4%)
- Superficial venous thrombosis (10%)
- BMI over 25 (2%)
- Immobilisation (8%)
- BMI over 25 and immobilisation (62%)
- Assisted reproduction (4%)
- Smoking (2%)
Interestingly pregnant patients are 75-96% more likely to have DVT in the left leg than the right leg.

Pregnant patients are also nearly 3 times more likely to have isolated DVT in the pelvic veins.

Up to 24% of pregnant patients with untreated DVT will develop PE with an associated 15% fatality rate.

Two thirds of deaths occur within 30 minutes of the embolic event.
1. Pathology & Imaging Pathway

- **WA Heath Imaging Pathways**
  - The normal physiological changes in pregnancy such as dyspnoea, tachycardia and leg swelling are also symptoms that a patient with a PE can present with.
  - D-Dimer starts to rise in second trimester and remains elevated for up to 6 weeks post partum.
  - V/Q or CTPA? – Be aware if V/Q inconclusive, CTPA warranted.

### Quality Initiatives

Imaging Pregnant Patients with Suspected Pulmonary Embolism: What the Radiologist Needs to Know

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**Table 1**

**Overview of CT Pulmonary Angiography**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages</td>
<td>Multiple trials documenting its high sensitivity and specificity in the general population. Short acquisition time and ease of access and interpretation. Capacity to definitively depict clot and provide an alternative diagnosis. Negative test effectively excludes diagnosis of pulmonary embolism in most low- to intermediate-risk populations.</td>
</tr>
</tbody>
</table>
Outline

1. Pathology & Imaging Pathway

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3. Physiology & Contrast Injection
2. Scan Technique & Radiation Dose

Scan technique;

- Same same or different?
- Low kVp?
- Low Dose SURE Exposure?
- Organ Effective Modulation (OEM)?
- Lead & Bismuth Shielding?
- Inspiration?
Scan technique:

- Bolus triggering with short start delays
- Use of fast CT scanner, 64 detector row or above
- Low kVp scanning
The risk for and strength of Valsalva manoeuvre may increase in pregnant women due to physiological stress factors and higher levels of anxiety.

Valsalva increases intra-thoracic pressure and substantially lowers contrast media influx.

Modest inspiration or even shallow breathing may be preferable to breath holding after deep inspiration.
2. Scan Technique & Radiation Dose

Influence of Respiratory Position on Contrast Attenuation in Pulmonary CT Angiography: A Prospective Randomized Clinical Trial

- 28 patients
- 14 inspiration technique, 14 expiration technique
- Expiration showed significantly higher contrast attenuation than inspiration technique (303HU vs 221HU)
- All other factors remained the same
- Thoughts?
Belgian study between January 2008 to July 2013. Number of CT scans of pregnant patients increased three fold.
2. Scan Technique & Radiation Dose

For pulmonary CTA, anthropomorphic modeling has shown that the use of lead shielding around the abdomen can effectively reduce the fetal radiation dose.

- Lead shielding also likely enhances the pregnant patient’s sense of protection.

- Bismuth shields decrease the radiation dose to the breasts as can organ based angular tube current modulation.
2. Scan Technique & Radiation Dose

Organ Effective Modulation (OEM) Version 7 software

- OEM: OFF
  - Relative Dose: 1.386
  - 29% Off

- OEM: ON
  - Relative Dose: 0.978
  - 29% Off

TOSHIBA
TOSHIBA MEDICAL SYSTEMS
2. Scan Technique & Radiation Dose

- Organ Effective Modulation (OEM) Version 7 software
- OEM can be set in a Manual SURE Exposure setting and can be saved in an Exam Plan
2. Scan Technique & Radiation Dose

- 1263 female chest CTs retrospectively analysed
- Only 63% of breast tissue found to be in reduced dose zone
- Relative dose reduction found to be 16%
- Bras with no metal that prevent lateral shift of breast tissue could be a solution
2. Scan Technique & Radiation Dose

The estimated fetal doses from typical radiologic examinations cause minimal fetal risk and therefore radiologic and nuclear medicine examinations that provide significant diagnostic information should not be withheld from pregnant women.

Although the risks are small, it is important to ensure that radiation doses are kept as low as reasonably achievable.
2. Scan Technique & Radiation Dose

Estimated Conceptus Doses from Single CT Acquisition

<table>
<thead>
<tr>
<th>Examination</th>
<th>Dose Level</th>
<th>Typical Conceptus Dose (mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra-abdominal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head CT</td>
<td>Standard</td>
<td>0</td>
</tr>
<tr>
<td>Chest CT</td>
<td>Standard</td>
<td>0</td>
</tr>
<tr>
<td>Routine</td>
<td>Standard</td>
<td>0.2</td>
</tr>
<tr>
<td>Pulmonary embolus</td>
<td>Standard</td>
<td>0.2</td>
</tr>
<tr>
<td>CT angiography of coronary arteries</td>
<td>Standard</td>
<td>0.1</td>
</tr>
<tr>
<td>Abdominal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdomen, routine</td>
<td>Standard</td>
<td>4</td>
</tr>
<tr>
<td>Abdomen/pelvis, routine</td>
<td>Standard</td>
<td>25</td>
</tr>
<tr>
<td>CT angiography of aorta (chest through pelvis)</td>
<td>Standard</td>
<td>34</td>
</tr>
<tr>
<td>Abdomen/pelvis, stone protocol*</td>
<td>Reduced</td>
<td>10</td>
</tr>
</tbody>
</table>

Probability of Birth with No Malformation and No Childhood Cancer

<table>
<thead>
<tr>
<th>Dose to Conceptus (mGy)</th>
<th>No Malformation (%)</th>
<th>No Childhood Cancer (%)</th>
<th>No Malformation and No Childhood Cancer (%)</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>96.00</td>
<td>99.93</td>
<td>95.93</td>
</tr>
<tr>
<td>0.5</td>
<td>95.999</td>
<td>99.926</td>
<td>95.928</td>
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<tr>
<td>1.0</td>
<td>95.998</td>
<td>99.921</td>
<td>95.922</td>
</tr>
<tr>
<td>2.5</td>
<td>95.995</td>
<td>99.908</td>
<td>95.91</td>
</tr>
<tr>
<td>5.0</td>
<td>95.99</td>
<td>99.89</td>
<td>95.88</td>
</tr>
<tr>
<td>10.0</td>
<td>95.98</td>
<td>99.84</td>
<td>95.83</td>
</tr>
<tr>
<td>50.0</td>
<td>95.90</td>
<td>99.51</td>
<td>95.43</td>
</tr>
<tr>
<td>100.0</td>
<td>95.80</td>
<td>99.07</td>
<td>94.91</td>
</tr>
</tbody>
</table>

*RadioGraphics 2007; 27:909–918 • Published online 10.1148/rg.274065149*
Outline

1. Pathology & Imaging Pathway

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3. Physiology & Contrast Injection
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- Physiology & Contrast Injection;
  - Same same or different?
  - Blood Volume?
  - Cardiac Output?
  - Contrast Volume?
  - Contrast Concentration?
  - Injection Rate?
Pregnancy requires dramatic changes in blood flow

Blood flow to the skin increases making pregnant women feel warmer and “glow”

Non pregnant women have approximately 100mL/min of blood flowing through the uterine artery

Pregnant women close to due date have approximately 350mL/min of blood flowing through the uterine artery

Amount of blood in a pregnant woman’s body increases by 40-45% during her pregnancy

This increase in blood volume requires an increase in cardiac output
Cardiac output up to 50% above non-pregnant levels leads to stronger dilution of contrast during the first pass.

Contrast injection protocols for pulmonary CTA have not taken into account the physiological changes during pregnancy with the result being that up to 28% of examinations are not fully diagnostic.

Injection protocols need to be adapted for pregnant patients.
Due to increased cardiac output, contrast will arrive earlier and peak enhancement will be lower than in non-pregnant women.

- Bolus tracking with short scan delay should be used. Use SUREStart with Voice Timing.

- Use higher iodine concentration contrast (350-400mL/mg)

- As cardiac output has increased by 50%, injection rate also needs to increase by 50%. For example; 4mL/s to 6mL/s, 5mL/s to 7.5mL/s etc.

- Increase in flow rate also requires an increase in contrast volume

- Volume = (Scan Time + 5) x Injection Rate
3. Physiology & Contrast Injection

- Is iodinated contrast safe during pregnancy?

- The Therapeutic Goods Administration (TGA) currently categorises the safety of iodinated contrast media during pregnancy as B1 or B2. Animal studies have not shown evidence of an increased occurrence of fetal injury. Limited cases of pregnant women receiving intravenous iodinated contrast media during pregnancy have shown no significant increase in the frequency of malformations or adverse effects.
3. Physiology & Contrast Injection

Is iodinated contrast safe during pregnancy?

A recent Japanese study has suggested that the risk of neonatal biochemical hypothyroidism increased from 0.7% to 2.4% in infants born to women who had iodinated oil contrast media used for hysterosalpingography immediately prior to conception. The risk was higher in women receiving higher volumes of contrast media. It is unclear whether this increased risk would also apply to water soluble media, which are more commonly used for this procedure in Australia and New Zealand.
3. Physiology & Contrast Injection

Is iodinated contrast safe during pregnancy?

- Recommendation;
  Infants born to women who received iodinated contrast media while pregnant should have testing for hypothyroidism in the neonatal period. In Australia and New Zealand, this is routinely performed in every neonate via a heel prick test as part of formal newborn screening programs.
1. Pathology & Imaging Pathway
   Very serious complication which can be difficult to diagnose

2. Scan Technique & Radiation Dose
   Consider all factors to get scan right first time. Remember ALARA

3. Physiology & Contrast Injection
   Adapt contrast injection protocol

Sorry Mum!
TOSHIBA MEDICAL